Racal Communications Ltd.

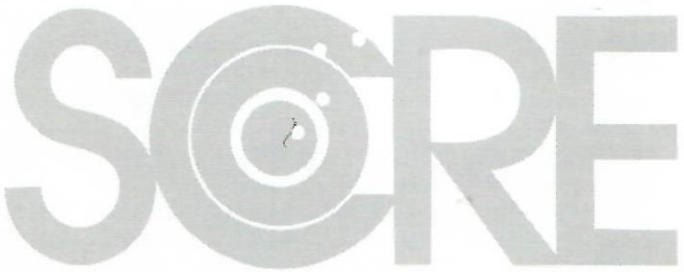
SCORE

Serial control of Racal equipment

INTRODUCTION

Selection of the functions of communication systems generally involves the setting of several controls to establish the correct operating frequency, mode of reception/transmission, filter bandwidth and any special conditions. In the past this has been achieved by the use of rotary and other selector switches mounted directly on the front panel of the equipment. However, the growing requirement for extended or remote control of communications equipment has resulted in the adoption of electrical means of determining the selection of these functions. For example, in the setting of frequency, the use of binary coded decimal (BCD) information fed to the equipment from an external source has been standard for a number of years. In HF equipment where the frequency may need to be determined to an accuracy of 1Hz over a frequency range extending to 30MHz, a total of 30 separate wires are needed for the BCD selection of frequency alone. In practice, to control all the other functions, a total of up to 50 wires may be necessary extended to a control panel associated with the equipment.

Where there is a requirement to operate over a long distance, it is not practicable to extend a cable with this number of wires, and a parallel-serial conversion is made so that a train of pulses is generated corresponding to the state of each control wire. This function has in the past normally been accomplished in separate remote control equipment, compatible with telephone circuits where necessary, and interfacing with the equipment under control by DC switching levels applied to the BCD and other encoded wires. Different manufacturers have adopted their own methods of coding since these have been entirely associated with the remote control equipment, and compatibility with other equipments was not normally necessary.



Racal developments now make it practicable to build the parallel-to-serial conversion circuits required into the radio equipment itself so that it can be controlled directly by a suitable pulse train compatible with computers and other automatic sources of data.

The Racal SCORE system has been evolved to provide this serial data in a format which gives full control of the complex functions of radio communications equipment over standard telephone circuits at a speed such that operators need not even be aware that the equipment is located at a distance. A dramatic demonstration of this capability is the 'free tuning' of synthesized receivers such as the RA 1784 over distances of 1,000 km or more. The system is equally applicable to transmitters and drive units.

The structure of the SCORE format provides for possible extension to a large number of complex control functions in the future for any type of equipment currently envisaged. It provides for the use of mini-computers or micro-processor based units which can relieve the operator from routine repetitive functions. Facilities are included for 'frame comparison' to reduce the possibility of incorrect settings even on noisy telephone circuits. It includes the possibilities of multi-address – where an operator can control many equipments from one position, of multi access – where more than one operator can obtain control of an equipment and for the addition of storage facilities to enable a number of channel settings to be programmed into the system.

THE EVOLUTION OF THE SCORE FORMAT

A careful study of the requirements for transmission of control information between communications equipments has led to the adoption of a 48-bit frame. This provides appropriate synchronization bits followed by word-identification bits, plus a 32-bit word of actual data. Different 48-bit frames may be used sequentially to provide almost unlimited amounts of data for the control of complex equipment. The system also enables the repetitive use of a single word, for example, where only the frequency of an equipment is being changed and the highest possible rate of change is required.

It is convenient to transfer numerical data such as frequency settings in BCD format, which has a structure such that in transmitting sequential digits, not more than four sequential '1' bits can be sent. Thus the synchronization code used in this system has been chosen as five successive '1' bits, preceded by an '0' bit at the beginning of the frame (i.e. Bits 0-5).

The next two bits (Bits 6 & 7) can be used for 'instantaneous' user functions such as transmit/receive switching, particularly in systems which make use of the first eight bits only (i.e. Bits 0-7) to increase the speed of response.

Bits 8-15 are used for system control and also for the data word identification bits which define the nature of the following data.

Bits 16-47 provide the main 32-bit word whose function is defined by the coding of Bits 12-15, and are arranged so that it is never possible to have five '1' bits in succession. With BCD data this is impossible, as described above, but with other forms of random data it is necessary to include '0' bits at intervals to ensure this cannot occur.

A very high degree of immunity to external noise is provided by 'frame comparison' which is a system of bit-by-bit comparison of the received data with that received from the previous frame, before execution of the command. This is particularly important for example in the case of a single operator provided with multi-address facilities for several equipments, which will remain on the previous settings unless re-addressed. This system halves the effective rate of data transfer which may not be desirable in the case of frequency setting because a high rate is required to maintain the illusion of continuous tuning, so this function may be disabled while frequency information is transferred. Any error will be immediately corrected in the next frame and will thus produce only a very short period of mis-tuning before being corrected.

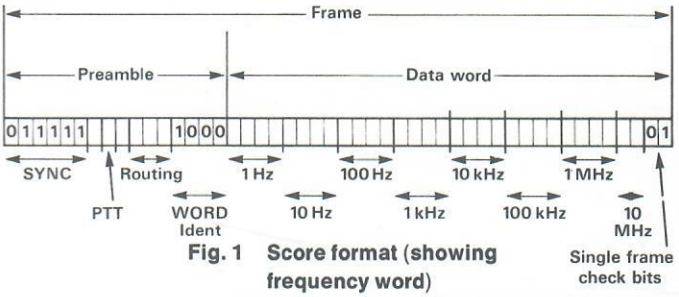


Fig. 1 Score format (showing frequency word)

Application to 'Free Tuning' Receivers.

Where a 'free-tuning' synthesized receiver is to be controlled, to give a smooth 'feel' at least 200 tuning steps must be provided per revolution of the main tuning control, which an operator must be able to rotate at up to 5 revolutions per second without losing control. This implies the use of a data rate capable of 1,000 new settings per second. Since a frequency setting alone may include up to 30 bits, an impossibly high data rate would be required unless some form of coding is included to reduce this rate.

One system in use elsewhere is to send 'incremental' information only, so as to reduce the 30 bits to a lower number representing the direction and magnitude of the increment. However, in practice this not only leads to very complex hardware to code and decode the various functions, – usually leading to the use of a micro-processor system within each receiver – but also implies that the absolute frequency settings are only available at the receiver itself, so that a continuous high-speed revertive display is necessary. Also error-protection must be very good so that incorrect increments can never be executed, and this inevitably slows up the data transfer.

The SCORE system uses a technique whereby the operator's control is directly associated with his local display, as in the RA 1772 receiver. The settings of the frequency indicators are then 'scanned' at fixed time intervals, determined by the available data rate, and full frequency setting information is sent at these intervals. In a typical 2,400 bit/s system these intervals are approximately 20 ms, and the effect to the operator's ear is of continuous and instantaneous tuning, even though when tuning rapidly many intermediate frequency settings are ignored between the scanning periods, so that the data rate is very much reduced. When the tuning rate is slowed down as the required value is approached, the size of the tuning steps is automatically reduced, and when the speed of rotation is only one revolution per second, all settings are transferred.

In practice at 2,400 bit/s an operator is scarcely aware of the effects of remote control, and at 1,200 bit/s or even 600 bit/s the effects are normally regarded as acceptable. Where 'free tuning' is not involved, fixed settings from decadic controls can be transferred at very much lower data rates, and at 100 bit/s a response time of a few seconds would be typical.

REMOTE CONTROL USING MODEMS

A particular feature of the SCORE format is that it is possible to achieve free tuning of synthesized receivers with data rates less than 2,400 bit/s especially when fine tuning only is required. Accordingly, a major feature of the SCORE range of equipments is that remote control over standard telephone circuits using 2,400 bit modems or even lower rates is practicable.

In the most simple case of a single receiver under control from a single control panel, the only equipment required is a pair of commercially available synchronous modems suitable for direct connection of the post office lines. The Racal-Milgo 26 LSI modems are recommended for this purpose and ancillary equipment available from Racal-Milgo enables a speech path using telephone handsets to be provided through the modems as an alternative to data, which is particularly useful whilst setting up or during maintenance operations.

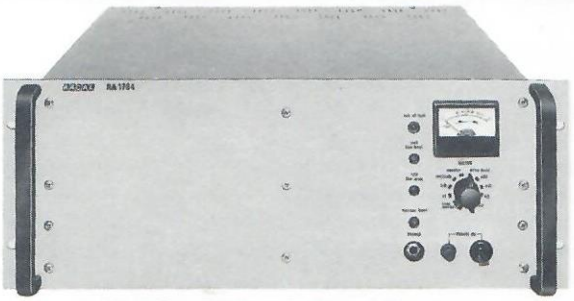
Where only small numbers of equipment are involved, and where distances are short so that line costs are moderate, it may still be practicable to use a line and a pair of modems for each equipment under control, particularly if by patching this enables some duplication to be provided to avoid the effects of line break problems. However, an alternative approach is by the use of a ' multi-mode ' modem which provides for a number of 2,400 bit/s channels over a single telephone circuit. An example of this technique is the Racal-Milgo 96MM modem which provides 4x2,400 bit/s channels over a standard telephone circuit operating at 9,600 bit/s. Thus four equipments can be controlled over a single telephone circuit by the addition of a four-way selection unit at the operator's control desk.

Furthermore, in situations where low data rates can be tolerated, standard multiplexing equipment is available from Racal-Milgo which enables a number of lower speed synchronous paths to be provided in conjunction with the standard 9,600 bit/s modem. Typically, a small amount of 'housekeeping' data needs to be transferred in these systems in addition to the useful data so that for example, 15 x 600 bit/s channels can be provided in conjunction with a 9,600 bit/s modem. Thus control of up to 15 receivers over a single telephone circuit is entirely practicable, using currently available modem hardware, if a data rate of 600 bit/s is acceptable. This would certainly be the case where most of the receivers are operating on fixed settings and only fine tuning adjustments are required, although in a system where most of the receivers were required for search operation, maintenance of not less than 2,400 bit/s is desirable.

The control of transmitters and their drive units has many similarities so that the SCORE techniques can be applied with equal ease to both receive and transmit systems. A line of units, specially designed for SCORE operations, has been added to the already comprehensive Racal equipment range so that full remote control systems of any complexity can be assembled.

UNITS USED IN THE SCORE SYSTEM

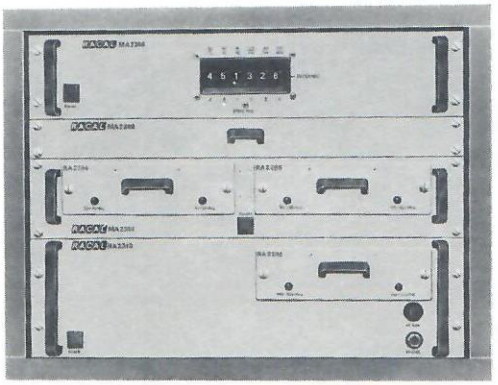
HF Receivers – RA 1784. The Racal RA 1784 is a SCORE controlled general purpose synthesized HF communications receiver designed for rack mounting with a front panel which is blank except for certain metering and monitoring facilities. It is suitable for a wide range of applications including surveillance, communications terminals and D F stations. SCORE format serial data is routed to a connector at the rear of the receiver and provides full control of all functions.



RA 1784 HF Remote Control Receiver

The RA 1784 receiver provides all the functions of the RA 1772 manually controlled receiver but with improved performance with respect to blocking, intermodulation products, and cross-modulation. External connections to the control unit (normally Type MA 1072) comprise two forward data highways for control and clock signals, and one return highway for revertive check information. In addition, a 600 ohm connection is required for the audio monitor path. External 600 ohm outputs for the traffic lines are provided from the receiver. The data rate of the serial control information is determined by the clock frequency; in systems for extended control this is normally 19,200 bit/s and for remote control using modems over telephone lines is 2,400 bit/s. However, the data rate may be as low as 100 bit/s for use in special applications, without change to the equipment.

In addition to the control of frequency, filter bandwidth, and mode, digital control of an internal synthesized BFO and the IF gain setting is also provided.



RS 2290 VHF/UHF Receiving System

VHF/UHF Receiver – RS 2290. The RS 2290 is a VHF/UHF receiving system using SCORE for the control of the receiver. The receiver itself comprises two basic units, the RA 2310 remote

control receiver, and the MA 2308 interface panel which accepts the SCORE data stream and converts it into parallel data.

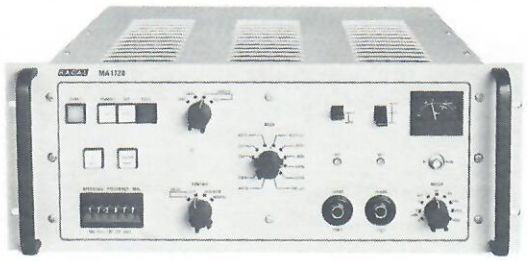
It should be noted that a total of four RF tuning heads are required to cover the complete frequency range. The RA 2294 covers 20 – 40 and 40 – 90 MHz, the RA 2295 covers 90 – 195 and 195 – 400 MHz and the RA 2296 covers 400 – 650 and 650 – 1,000 MHz. One of these heads can be stored and operated within the RA 2310 receiver, and the remaining two can be operated and automatically switched when used in the MA 2303 active stowage unit. Above 1000 MHz an additional RF tuning head type RA 2297 is necessary. This is rack mounted and occupies a panel space of 1.75 in. Control of all these heads is obtained from the MA 2308 interface panel in conjunction with the SCORE data.

In addition to the control of frequency, filter bandwidth and mode, provision is made for selection of AGC time constants, BFO frequency, carrier operated relay and audio squelch circuitry.

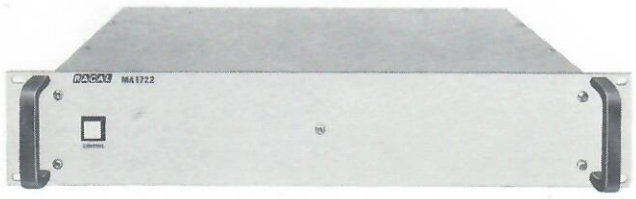
Transmitter Drive Units – MA 1720/MA 1722. The MA 1720 is a synthesized transmitter drive unit provided with facilities for external control over parallel lines. The MA 1722 serial adaptor unit is used with the MA 1720 for compatibility with the SCORE system.

All the functions of the MA 1720 may be controlled from the front panel but by selecting 'Remote' on a front panel switch, control is transferred to an external source. A lamp is illuminated on its front panel when the MA 1722 is included for interfacing between the SCORE serial data and the parallel data required for the MA 1720. It also provides for revertive check indication of the transmitter status (Standby/EHT ON/Reduced Power etc.) in the SCORE format.

As in the case of the RA 1784, the connections required to the MA 1722 are forward and revertive data lines and a clock line, as well as 600 ohm traffic lines. The data rate of the serial control information is determined by the clock frequency.



MA 1720 Synthesized Drive Unit



MA 1722 Serial Control Unit

Receiver Control Units – MA 1072. The MA 1072 is a remote control unit designed for communicating SCORE format with the RA 1784 receiver. All functions are selected by illuminated push buttons with instantaneous contact operation. The illumination of the push buttons is separately controlled from the button operation, so that in systems using alternative sources of control the unit can indicate the settings supplied from the other sources.

'Analogue' controls for BFO settings and IF gain operate shaft encoders which provide digital information for the SCORE format.

In systems involving only one receiver and MA 1072, the operation of the front panel controls is substantially identical to that of a manually operated receiver. Two STATUS buttons are then applicable:–

The CHECK button permits interrogation of the receiver itself and display of the actual settings which exist within the receiver. Normally this would result in no change of the display shown on the front panel.

The RECALL button operates an 'exchange' type memory into which all the settings from the front panel are placed, and the previous settings in the memory recalled to the front panel and sent to the receiver. The receiver can then be reset to new settings and a second operation of the RECALL button will cause the receiver to revert to the settings previously placed in the memory.

MA 1072 HF Receiver Control Unit

In systems where more than one operator or a computer is involved, the MA 1072 also operates as a routing centre for the data of the system, and the remaining two STATUS buttons are operative. For example, if two operators are involved, and each has a single receiver controlled by a single MA 1072 with a data interconnection between their control units a typical sequence of operation could be as follows:–

Operator 'A' locates a transmission of interest and informs Operator 'B' simultaneously pressing the STATUS 'OUT' button on his control unit. Operator 'B', when ready to receive data, presses the STATUS 'IN' button on his control unit which places the settings already on his unit into the RECALL store, and displays on his unit the data received from Operator 'A'. He then cancels the 'IN' button and can tune his receiver manually to any new settings required. Operation of the RECALL button will recall the initial settings and place the current settings into the RECALL store.

Where a computer is involved in the system, data from the computer is routed through the MA 1072 to the receiver under control, and the settings supplied by the computer are displayed on the MA 1072 control panel.

Receiver Control Units – MA 2305. This unit is based on the MA 1072 and is identical except that it provides the functions required for the control of the RS 2290 VHF/UHF receiver instead of the RA 1784 HF receiver. In principle, all functions are identical and the modes of operation of the STATUS buttons are the same.

MA 2305 VHF/UHF Receiver Control Unit

Frequency Entry Pad – MA 1083

The MA 1083 frequency entry pad is connected to the MA 1072 by a front panel connector, and enables an operator to enter frequencies from a calculator type keyboard, or to call up one of 40 programmed frequencies from the pad to the MA 1072. Programming of the frequencies is undertaken by the use of the keys on the frequency entry pad. It should be noted that this unit does not provide for programming of mode or filter bandwidths. The MA 1083 can also be used to provide frequency programming in conjunction with the MA 2305 or VHF/UHF receivers, and with the MA 1090 for HF transmitters.

MA 1083 Frequency Entry Pad

Multi-Address Units – MA 1082. The MA 1082 is an address selection unit providing equipment addressing facilities for communications systems using the SCORE format. Each MA 1082 encodes the 100 equipment addresses of the SCORE system for subsequent decoding by up to ten MA 1078 address decoders at the receiver or transmitter site. Ancillary control units such as antenna selectors and audio patching units may also be included in the addressing system.

The MA 1082 sends an equipment addressing word through the relevant decoding unit to the unit selected. Revertive check information from the selected unit is returned to the address selector. Once confirmation of the address is received the full control information from the appropriate receiver or transmitter control unit is routed to the required unit. All controls are front panel mounted together with LED matrix address indicators, fault and self-check indicators. Control lines are provided through rear panel connectors to facilitate multi-addressing of other ancillary control units using the SCORE format.

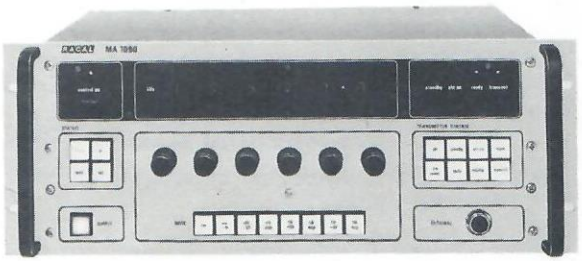
MA 1082 Address Selection Unit

Multi-Address Units – MA 1078. The MA 1078 is an address decoding unit designed to operate in communications systems using the SCORE format. Each unit will decode up to ten addresses, and ten decoders may be used in parallel to cover the full 100 address capacity of the SCORE system. A slave facility allows two equipments to receive the same control data for diversity reception, DF and simplex operations. The MA 1078 also permits revertive check information to be routed from the selected unit.

Address selection may be from a central processor, the MA 1082 address selection unit or locally through a rotary switch on the front panel. When a specific address is selected locally the remaining nine are still available for remote control. An indicator on the front panel displays the selected address.

MA 1078 Address Decoding Unit

Transmitter Control Units – MA 1090. Based on the MA 1072, the transmitter control unit MA 1090 is designed for single, multiple or computer control of transmitters using the SCORE format for remote or extended control systems. Frequency selection is by six rotary switches with a six digit LED display to show the selected frequency. Control of all the transmitter drive unit functions (MA 1720) is provided through push buttons which are illuminated when operated. An external connector on the front panel enables the operator to use the MA 1083 frequency entry unit.



MA 1090 Transmitter Control Unit

SCORE Display Units – MA 1091. Designed as a display unit for use at the control or remote end of a SCORE multi-address system the MA 1091 status display unit is used to indicate the operational status of up to ten transmitters. The main indication is by ten columns of eight functions with amber LED's to show reduced power and no data conditions, green for normal conditions, and red to indicate fault. An alarm enable button energizes an external warning when a fault is detected and a test button can be operated to check the serviceability of all warning LED's. Other versions of the MA 1091 are available with a ten column five row display for HF receivers or a ten column four row display for VHF/UHF receivers.

MA 1091 Status Display Unit

Full details of the equipments mentioned are given in separate publications available on request.

APPLICATIONS AND TYPICAL NETWORKS

In multiple communications systems it is a frequent requirement to display a considerable amount of information to a single operator. The Racal approach is to make use of standard computer hardware and visual display units (VDU's) to provide many of the control functions and the displays necessary for operation of such stations. The VDU screen is capable of displaying the frequency, mode, bandwidth and other settings in addition to station identification, on up to 15 receivers simultaneously, and the availability of alpha-numeric characters provides for information to be shown which could not be displayed using conventional techniques. Furthermore, the nature of the display can be changed at will by altering the computer software, so that alterations to the type of data, the size of display, and the number of parameters displayed may be made at any time.

To understand the capabilities it is convenient to consider a typical system which can be operated using a computer, VDU and ' floppy disk ' store. A total of 14 receivers is involved under the control of a single operator who is provided with a VDU and standard keyboard such as the MA 1098 and with an MA 1072 control unit. By typing appropriate commands on to the VDU keyboard he can display two alternative sets of information :–

(a) A 'receiver list' which shows in numerical order the 14 receivers under his control and the settings of all the functional controls of these receivers, together with some form of short station identification. An indication is also available of the RF signal level on each receiver, and a fault indication in case any malfunction of a receiver occurs. At the bottom of the screen is displayed an 'editing' line which enables data to be retrieved from the channel list described below and checked or edited before incorporation into receiver settings.

(b) A 'task' which can store previously entered settings on a large number of known channels of interest. Typically this could be for about 100 channels stored on ten pages, each displaying 10 channels. The page arrangement is made so that an operator's request to display a particular channel will result in the VDU showing the succeeding 10 tasks at the same time. New channels are entered by the use of the editing line at the bottom of the page which enables insertion and correction of new data before entering into the computer store.

The method of operation can be in a number of different ways. If the operator is in control from the computer keyboard, new frequencies may be typed into the computer store by use of the standard typewriter keys. Information on a new task would then be entered into the editing line before insertion into the list with an appropriate channel identification number, and then transferred to the appropriate receiver. This operation involves recalling the receiver list which provides confirmation that the receiver is not already set to a 'wanted' channel before the new channel can be inserted. When the new task is inserted into the receiver, provision is made for 'on line' operation indicated by a cursor mark on the VDU screen of this particular receiver. Under these conditions, corrections may be made to the receiver settings either from the VDU keyboard or from the MA 1072 without alteration to the settings of the stored task. The MA 1072 may be used to set the receiver to completely different settings to those previously inserted, and these settings may then be recalled into the computer store and allocated a number in the channel list. In this example the operator thus has full flexibility of continuous control recall of 100 tasks, multi-address of 14 receivers, and display of current settings of any of these receivers, all in the space of a single MA 1072 and a VDU.

Other capabilities are available in the computer system which are not currently available from the dedicated units described in the previous section. A particular example of this is the 'scanning' facility which enables the operator to allocate one receiver to scan sequentially through a series of tasks designated in the list by typing an asterisk at the start of the station identification, and the dwell time of the receiver on each of these channels can also be programmed by the operator. The receiver then sequentially tunes to each of these channels and measures the RF signal level. If this exceeds a value preset by the operator, the scan can be stopped and an alarm signal initiated if required. Simultaneously, the settings of the receiver can be sent to another receiver which will proceed to monitor continuously this task, perhaps in conjunction with a tape recorder, teletype, morse translator etc.

TYPICAL SYSTEM CONFIGURATIONS

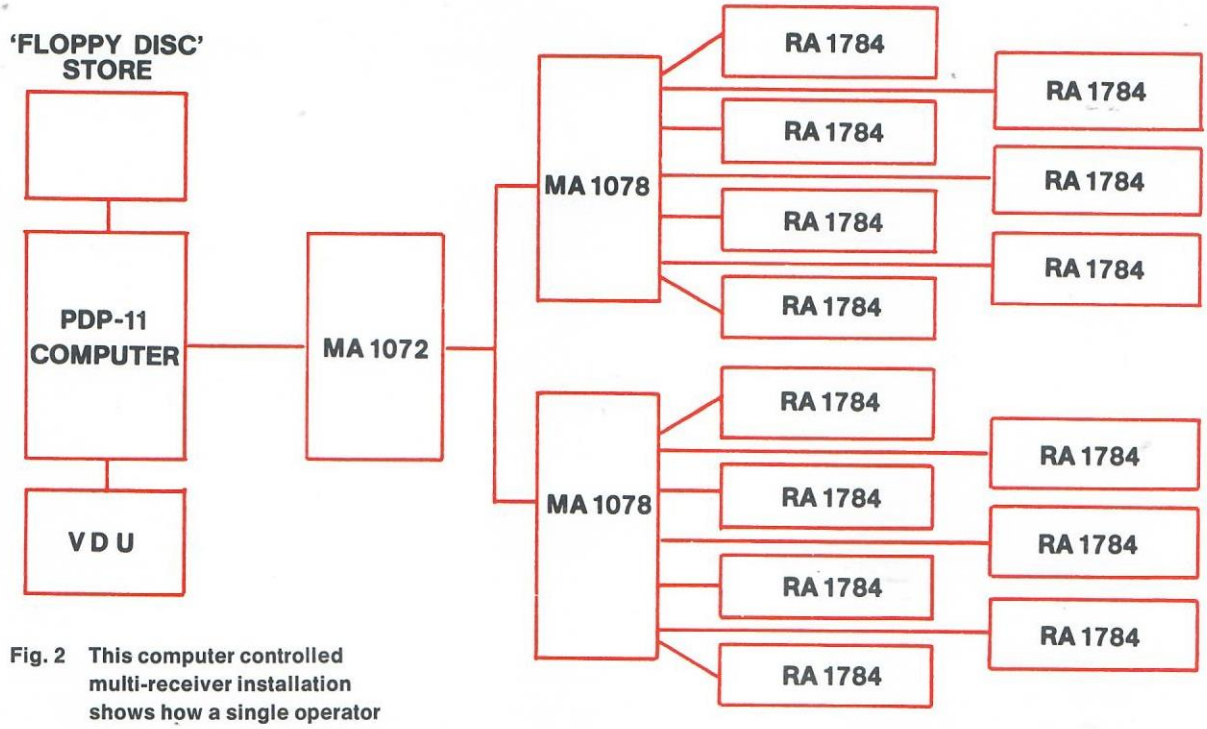


Fig. 2 This computer controlled multi-receiver installation shows how a single operator may control 14 receivers and includes storage for 100 channels and provision for auto search/scan

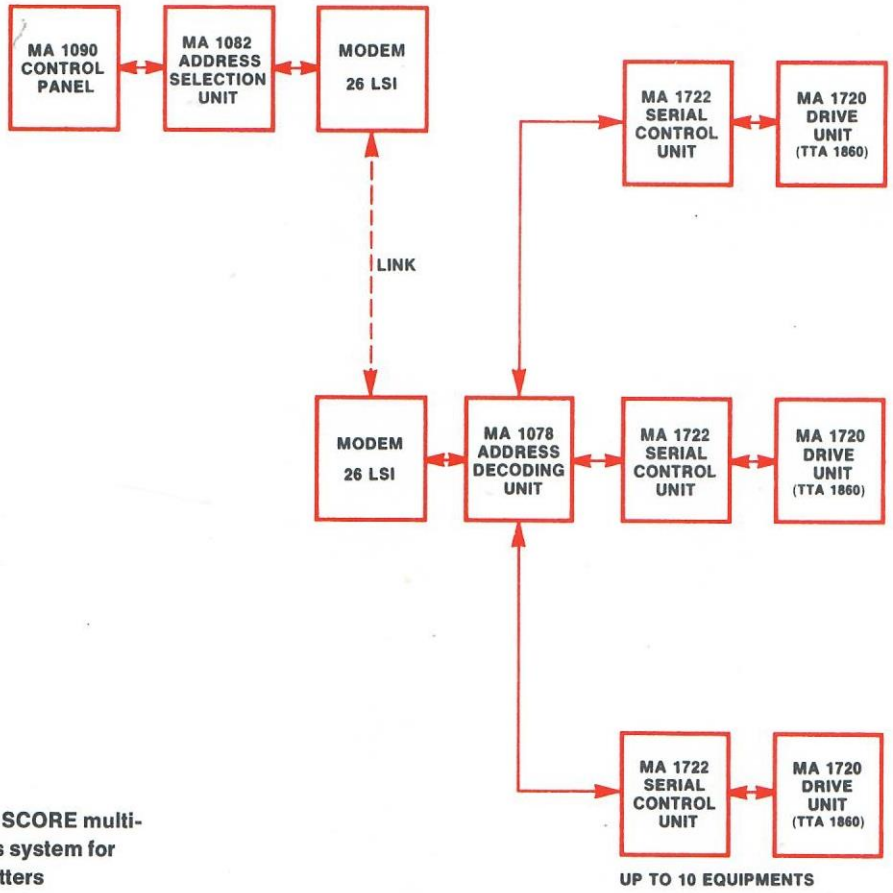

MA 1090 CONTROL PANEL
MA 1082 ADDRESS SELECTION UNIT
MODEM 26 LSI
LINK
MODEM 26 LSI
MA 1078 ADDRESS DECODING UNIT
MA 1722 SERIAL CONTROL UNIT
MA 1720 DRIVE UNIT (TTA 1860)
MA 1722 SERIAL CONTROL UNIT
MA 1720 DRIVE UNIT (TTA 1860)
MA 1722 SERIAL CONTROL UNIT
MA 1720 DRIVE UNIT (TTA 1860)
UP TO 10 EQUIPMENTS

Fig. 3 Typical SCORE multi-address system for transmitters

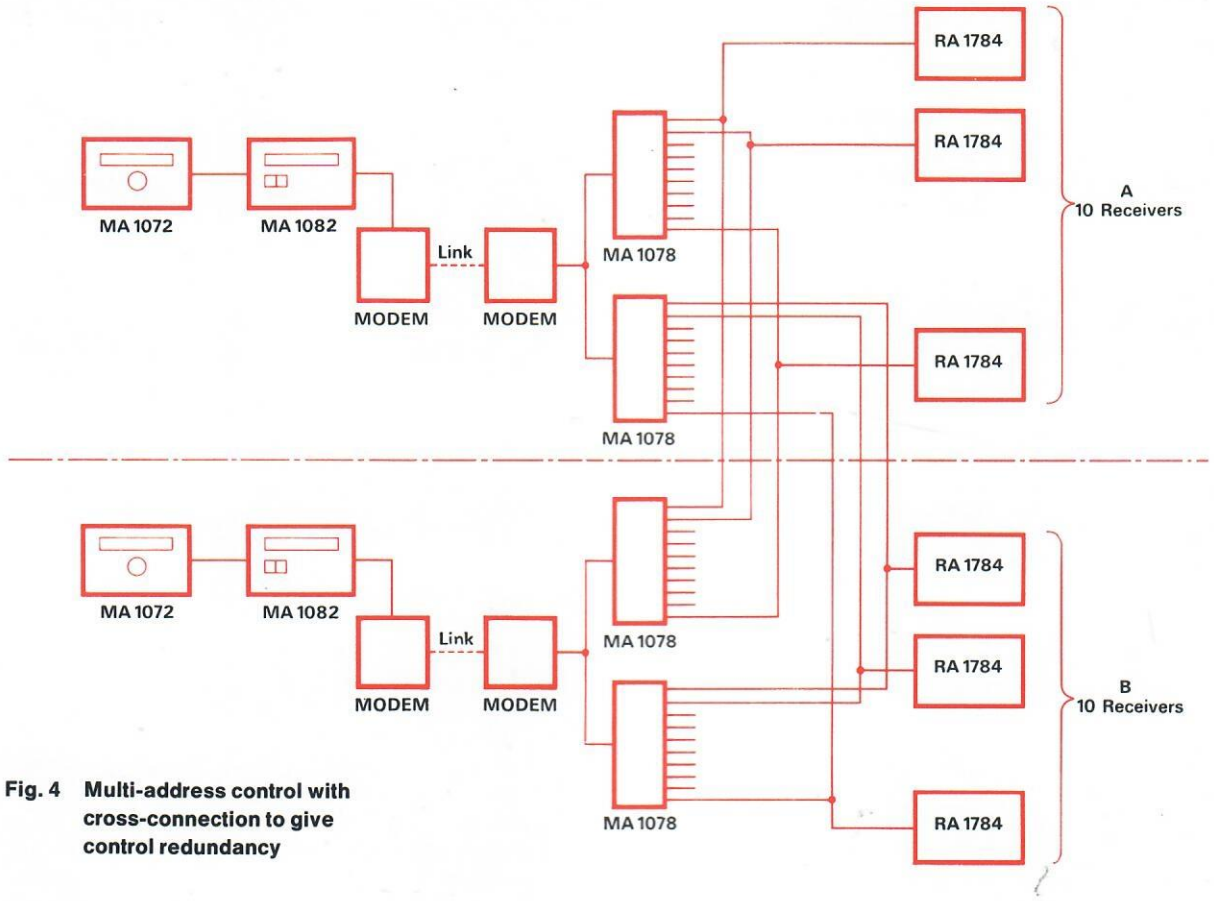


Fig. 4 Multi-address control with cross-connection to give control redundancy

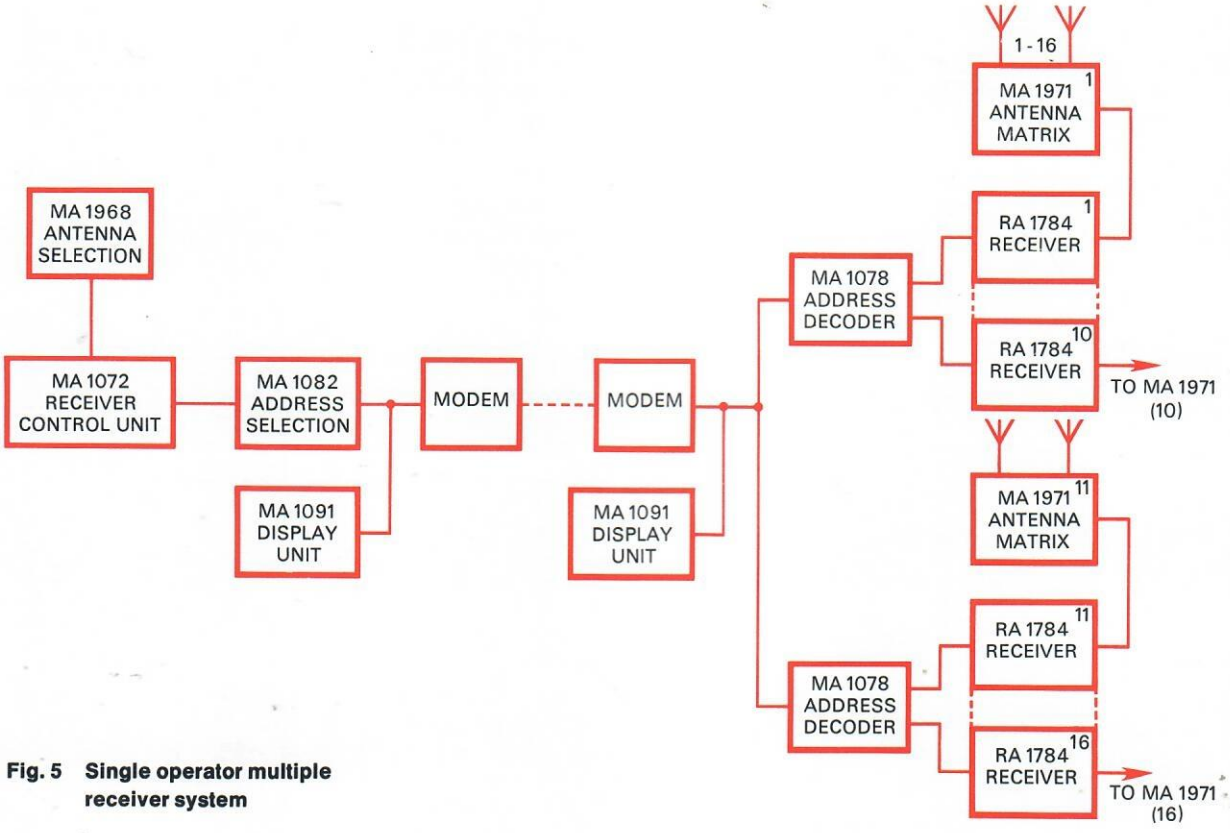


Fig. 5 Single operator multiple receiver system

Racal reserve the right to vary in detail from the description and specification in this publication.

Publication Number 7041-2 Printed in England EC/R178/GP © 1978

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